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ORIGINAL RESEARCH

Assessing physical activity in inpatient rehabilitation—sensor-based validation of the PAIR

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Abstract Increased physical activity is positively associated with better health in community-dwelling older persons. It is unclear whether physical activity also influences success of inpatient rehabilitation. For the assessment of physical activity in inpatient rehabilitation the Physical Activity in Inpatient Rehabilitation Assessment (PAIR), a short questionnaire based on five questions, was developed and preliminary validated. In this study, the PAIR was validated against a sensor-based physical activity measurement. Seventy functionally impaired and cognitively mostly intact patients of a German geriatric inpatient rehabilitation clinic who had undergone hip surgery (n=62 women, median age=83 years) participated. Physical activity was measured using the PAIR and a sensor-based activity monitor (Physilog ®; BioAGM, CH). Assessments were conducted at admission (T1) and 2 weeks later (T2) during the rehabilitation process. To assess concurrent and predictive validity, Spearman correlations and linear regression models were calculated using sensor-based walking activity and uptime activity (walking and standing time) as dependent variables. Criterion-related concurrent validity using physical activity sensors was weak to moderate. Correlations were slightly higher at T2 (r=0.45-0.53) than at T1 (r=0.44-0.46). The objectively measured variance of physical activity, explained by the PAIR, ranged from 25 to 43 %. PAIR activity scores and sensor-based walking or total activity increased in a dose-dependent manner, confirming the scoring system of the PAIR. The application time was usually less than 2 min. The validity of the PAIR is weak to moderate when compared to a sensor-based activity monitor and comparable to existing physical activity assessments for community-dwelling older adults.

Keywords Geriatric assessment · Inpatient rehabilitation · Psychometric properties · Validity · Physical activity

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Introduction

Physical activity (PA) has been shown to be beneficial for diverse aspects of physical and mental health in community-dwelling older adults [10, 29]. It has been included in functional assessments concerning the aspect of physical frailty [3] and there is growing interest to use PA as one parameter to describe progress in rehabilitation [18, 23]. Former studies have used proxies to calculate frailty scores [32] or functional parameters with floor or ceiling effects to describe progress in rehabilitation.

Measurement of PA in inpatients has, however, been always difficult. Prescribed exercises do not reflect activity in its participation sense as mentioned in the International Classification of Functioning Disability and Health (ICF) [36]. Patterson and colleagues [31] observed six patients for 12 h in inpatient rehabilitation and found very low activity levels between treatment sessions. An overall PA score was not constructed. In a recent publication in inpatients, PA (as measured by actigraphy) predicted physical function levels in hip fracture patients [37].

The question whether questionnaire-based instruments or performance-based/sensor-based approaches better reflect "real" PA levels has always been and still is a matter of debate[35]. With regard to the direct PA measurement, the doubly labelled water method is usually seen as the gold standard in adults [34]. However, this method is not feasible for everyday use. Therefore, newer approaches include sensor-based technology to be worn on the wrist [14, 19], on the trunk [2, 28] or on the legs [15]. Yet, these tools can be expensive and acceptability is limited due to cumbersome attachment techniques as mentioned above. Therefore, sensors might not be readily available in any rehabilitation unit. Although many different questionnaires for community-dwelling older adults have been proposed and validated [20], an interview-based and validated assessment to measure PA in inpatients did not exist. The only tool mentioned in recent literature, a questionnaire on self-initiated and treatment-associated mobility that was asked every day during the hospital stay, has been associated with different health outcomes in two earlier studies [6, 41]. A previous validation of this instrument was not reported.

The Physical Activity in Inpatient Rehabilitation assessment (PAIR) was developed to allow an estimation of PA levels in inpatients without the use of technical equipment [11]. The idea of the PAIR was to provide a cost-saving and widely available tool which is easy to implement within the rehabilitation process. An initial validation study against physical functioning as a proxy measure for PA has demonstrated reasonable validity and good sensitivity to change despite its very short administration time [12].

Because most current tools for community-dwelling older adults have been validated using different gold-standard activity measurement techniques, we aimed to improve validation quality by choosing mobility sensors that include triaxial accelerometers and a gyroscope to assess both walking activity and uptime activity. With regard to criteria established by Murphy in 2009 [27], sensors were chosen because of the expertise of the research team, clinical availability and because they can validly and reliably capture exercise and lower mobility activity in older adults [28].

The aim of this study was to examine the concurrent validity of the PAIR against a sensor-based PA measurement in a sample of inpatient older adults able to walk at baseline and to compare practicality of the PAIR and the sensor with regard to application time.

Methods

Participants and design

A consecutive sample of 70 geriatric patients from the MEMBeR study [23] was recruited in a geriatric rehabilitation centre in the southwest of Germany between September 2007 and August 2010. The inclusion criteria were being 65 years or older and admittance for rehabilitation after hip fracture or elective hip replacement. Exclusion criteria were presence of major depression, severe cognitive or mental disorder, severely impaired vision and insufficient understanding of the German language as checked by the responsible senior consultant at admission. Patients were screened on admission and asked whether they would agree to participate. All participants gave written informed consent. The study was approved by the ethical committee of the local university.

Assessments

Assessments were performed 1 day (physical performance, questionnaires) and 2 days (PA assessment) after admission (T1) and 2 weeks later (T2) in the rehabilitation centre. All assessments were conducted by four trained therapists.

Physical Performance was assessed by modified items of the Short Physical Performance Battery [16] at T1 and T2.

Balance test: balance was tested while participants stood in different positions without any support. The positions were open stance with feet comfortably apart; closed stance with feet side by side; semi tandem stance with feet parallel, heel of one foot touching the big toe of the other foot on the inner side; and tandem stance with feet standing in line, heel of one foot touching the tiptoe of the other foot. Only one attempt was allowed in each position. If a participant was able to hold a position for 10 s, the next most challenging position was tested. The sum of the seconds performed in all positions was calculated, with a maximum of 40 s.

Gait speed: habitual gait speed was timed (stopwatch) over 4 m, with an additional 3 m for acceleration and 3 m for deceleration [24]. The mean gait speed of the two attempts was taken for the analysis [meters per second].

Five-chair rise: performance of sit-to-stand transfer was assessed by timing (stopwatch) five chair rises with the use of arm rests being allowed [22]. Standing up and sitting down five times in habitual speed starting in sitting position and stopping after sitting down the fifth time. The mean time of chair rise performance of the two attempts was taken for the analysis [seconds].

The *Barthel Index (BI)* was assessed at T1 by the nursing staff responsible for the individual patient according to the "Hamburger Manual" [25], which was established to increase reliability.

In order to describe the *cognitive status* of the study sample, the Short Orientation Memory Concentration test [21] was administered during admission (T1). This test assesses temporal orientation, counting backwards, reciting months backwards and memorizing an address. The range of results varied from 0 (best) to 28 (worst) errors. A score of 11 or more has been shown to indicate possible dementia.

Physical activity was measured with a Physilog ® activity monitor (BioAGM, CH). The device consists of a miniaturized encapsulated data-logger, rechargeable batteries, MMC memory card, triaxial accelerometers (ADXL 202, Analog Device, ±2 g) and single axis gyroscope (ADXRS 150, Analog device, ±200 deg/s). The small size (95×60×22 mm) and its lightweight (122 g) allowed for attachment on the person's chest by a harness without hindering the subject.

The analysis algorithm is described elsewhere in detail and has been validated against opto-electronic systems, video and personal observation in different groups of subjects including older adults [28, 30] and patients with Parkinson's disease [33]. Overall accuracy for the detection of physical activities in older adults was higher than 90 %. For detection of walking, standing, sitting and lying, sensitivity between 87 and 99 %, and specificity between 87 and 99 % is documented. Chest acceleration as well as the chest angular velocity were stored digitally with a sampling frequency of 40 Hz on a MMC memory card.

The participants wore the device during the day (from breakfast until preparing for bed in the evening) for 1 day and were not allowed to take it off except for therapies like massage or radiological investigations. Data used for analysis were restricted to 9 h (9 AM to 6 PM). The reported values in this paper were the cumulative time [minutes] of walking (meaning three consecutive steps or more) ($walk_{cum}$) and the cumulative time walking and standing (uptime).

The *German version of the PAIR* was assessed as explained in detail in a previous publication [12] at T1 and at T2. In brief, the PAIR consists of eight items that focus on a patients' radius of ambulation between treatment sessions. The eight items are asked starting with the least difficult task, stepwise going towards the most difficult task. The PAIR is shown and explained in detail in Table 1.

During inpatient rehabilitation, patients received a standard therapy intervention consisting of physiotherapy and occupational therapy as required. Therapy was offered in group (six to nine sessions per week) and individual (three to eight sessions per week).

Table 1 The Physical Activity in Inpatient Rehabilitation (PAIR) assessment

Between therapy sessions….	To what extent	Score
1. …I was mostly lying in bed in order to recover	Yes	0
2. …I was mostly sitting in my room in order to recover	Yes	1
3. …I was undertaking little walks on the ward	Yes sometimes	2
	Yes often	3
4. …I was undertaking little walks outside the ward (i.e. cafeteria)	Yes sometimes	4
	Yes often	5
5. … I was undertaking little walks outside the hospital	Yes sometimes	6
	Yes, often	7

The interview can be started with the least difficult task, stepwise going towards the most difficult task or vice versa. It can be introduced as following: "Now we want to know what you have been doing between therapy sessions". If the patient does not fill out the assessment on his or her own, the questions should be asked as follows: "Between therapy sessions, were you mostly lying in bed in order to recover" and so on. Regardless of the answer, continue to the next task because patients might sit and lay down a great amount of the time and would answer yes to both questions. *Please always continue to the most difficult task if the patient's mobility is good enough to theoretically undertake walks on his or her own. Be careful not to underestimate the patient's physical activity*

The definition of sometimes and often is defined as follows: "yes, sometimes" should be scored if the task has been accomplished *less than four times* a week. "Yes, often" can be scored when the patient has done the task *four and more times* a week

Severe cognitively impaired elderly might be assessed using proxies (i.e. relatives or nurses if applicable)

Please note that it is irrelevant what the patient has done during therapy sessions. Instead, the questionnaire aims to assess physical activity, even in the context of participation with relatives

Wheelchair use (not validated): what should be scored, if a patient is being pushed along the ward or even outside the hospital in a wheelchair, but is not able to leave the bed without assistance? Because the PAIR has not been developed as an assessment of physical function we believe that the activity and not the functional capabilities (even with the assistance of relatives or visitors) should be scored. However, if the patients was urged to go outside and if he/she was absolutely passive during the walk we would not regard this activity as physical activity in the sense of the ICF. Further studies are needed to clarify this issue

The *final score of the PAIR is the maximum score*, not a cumulative score. For example: if the patient manages to undertake little walks on the ward every day, but, during the rest of the time sits in his chair, he or she would score 4 points

Statistics

Due to non-parametric distribution of some parameters median, minimum, maximum and inter-quartile range were used for descriptive statistics. Wilcoxon-sign-rank test was calculated to show differences between performance at T1 and T2. Criterion-related validity is demonstrated as concurrent and predictive validity [38]. To assess *concurrent validity* the association between PAIR scores at T1 and T2 and sensor-based cumulative minutes walking and uptime (walking and standing) at T1 and T2 was calculated using Spearman rank correlations [40]. To assess *predictive validity,* PAIR scores, measured at T1 and T2, were used as independent variables in a linear regression model to predict PA as measured by the Physilog device as a dependant variable. Again, both, cumulative minutes walking and uptime (walking and standing) were considered. The Spearman's Rho was interpreted according to Domholdt: 0.00–0.25=little if any correlation, 0.26–0.49=weak correlation, 0.50–0.69=moderate correlation, 0.70–0.89=strong correlation, 0.90–1.00=very strong correlation [13]. To assess *absolute validity* Bland-Altman plots were calculated. Because Bland-Altman plots require that the two methods for measuring the same characteristic use the same scale of measurement, a statistically exact conclusion could not be drawn. Yet, we still considered this the best approach to qualify clinically relevant uncertainties across the measurement range [5].

For the scoring figure, median sensor-based activity values have been calculated for each PAIR score using Microsoft Excel 2007 (Microsoft Corp.). All other analyses were conducted using SPSS version 16 software (SPSS, Chicago, IL, USA).

Results

Descriptive

Patients were mostly female (n=62, 88.6 %) and showed a wide range of cognitive abilities. Baseline characteristics are shown in Table 2. All parameters of physical function and PA improved during rehabilitation as shown in Table 3. Some tests of physical performance showed floor or ceiling effects, since not all patients were able to perform the tests.

At T2 five patients were not available for the sensor-based PA measurement because of inter-current illness (n=2), refusal (n=2), or early discharge (n=1).

Table 2 Baseline characteristics

Characteristics	Median	First–third quartile	Minimum–maximum
Age [years]	83	79.0–87.3	67–98
Height [cm]	156.5	151–161	136–181
Weight [kg]	64	55.8–74.3	40–96
Barthel index (0–*100*)	57.5	50–70	15–90
SOMC (*0*–28)	8	5.5–11	0–25
Gait speed [m/s]	0.35	0.26–0.46	0.09–0.83
5 Chair Rise [s]	34.1	27.9–49.3	16.2–96.6
Balance [s]	23.2	19.0–31.7	0–40
Cumulative walking time [h]	0.16	0.06–0.35	0–1.22
Cumulative uptime [h]	1.67	0.97–2.34	0.04–4.39
PAIR (0–*7*)	1	1–2	0–5

Best scoring values are in italics

SOMC Short Orientation Memory Concentration test, *PAIR* Physical Activity of Inpatient Rehabilitation questionnaire

Table 3 Physical activity and physical function at admission and 2 weeks later

	Admission Median (first–third quartile)	2 weeks later Median (first–third quartile)
Gait speed [m/s]	0.35 (0.26–0.46)	0.52 (0.42–0.62)
5 Chair Rise [s]	34.1 (27.9–49.3)	26.8 (19.9–36.0)
Balance [s]	23.2 (19.0–31.7)	30.0 (22.2–37.1)
Cumulative walking time [h]	0.15 (0.06–0.35)	0.37 (0.18–0.55)
Cumulative uptime [h]	1.67 (0.97–2.34)	2.07 (1.59–2.81)
PAIR (0–*7*)	1 (1–2)	3 (1–5)

Best scoring values are in italics

All changes from admission to 2 weeks later were statistically significant (p<0.0001)

PAIR Physical Activity of Inpatient Rehabilitation questionnaire

Application time

The PAIR questionnaire was administered in approximately 1 to 2 min, whereas the sensor-based PA measurement took approximately 15 min including fixing, taking off and analysis (without the wearing time).

Criterion-related validity

Evidence for the validity of the PAIR is shown in Table 4. Concurrent validity for sensor-based walking and uptime at T1 and T2 was demonstrated with Spearman correlations between r=0.443 (weak) and r=0.525 (moderate) with higher coefficients of correlation for walking and T2. Regression analysis including the PAIR scores at T1 and T2 explained 25 to 46 % of the variance of cumulative walking time and uptime at the same time with higher percentage for walking at T1 (Table 4). All results were statistically significant at the p<0.0001 level.

Absolute validity

Bland-Altman plots revealed slightly heterogeneous pictures at T1 and T2 with overall higher uncertainties in the lower scale range of the PAIR. The plots indicate that the 95 % limits of agreement between the two methods ranged from −2 to +2 points in the PAIR. The two methods, therefore, do not consistently provide similar measures because there is a level of disagreement that includes clinically important discrepancies of up to 2 points (not shown).

Scoring system

PAIR activity scores and median activity values of the sensor-based PA measure increased in a dose-dependent manner, with the exception of score "six" (especially concerning overall activity levels), as shown in Fig. 1.

Table 4 Criterion-related concurrent and predictive validity of the PAIR

Association of the PAIR	Spearman's rho
Concurrent validity at admission (T1, n=70)	
Walking and standing activity (uptime)	0.443
Walking activity	0.457
Concurrent validity 2 weeks later (T2, n=65)	
Walking and standing activity (uptime)	0.450
Walking activity	0.525
PAIR in a regression model	Variance explained
Predictive validity (T1, n=70)	
Walking and standing (uptime)	29 %
Walking activity	46 %
Predictive validity (T2, n=65)	
Walking and standing (uptime)	25 %
Walking activity	33 %

PAIR Physical Activity of Inpatient Rehabilitation questionnaire

All results statistically significant at the $p<0.0001$ level

Discussion

The PAIR demonstrated weak concurrent and predictive validity when compared to an objective PA assessment at admission and weak to moderate correlations 2 weeks later in older, ambulatory adults in an inpatient rehabilitation unit. It was easy to administer and its scoring system was valid with exception of the score "six".

There are several possible reasons for the mostly weak to at best moderate correlations with the sensor-based activity measure. First, the sensor-based system was not only worn between treatment sessions, because it could not be switched off and on before and after the treatment. The PAIR however, specifically asks for activity between therapy units. Second, the device was only worn throughout the day (from 9 am to 6 pm) and participants could have also rated their activity according to what happened before and after this time. In addition, sitting and lying activities as reported for score one and two of the PAIR are not captured by the sensor. It also has to be mentioned that the PAIR could, like other interview-based or proxy-based activity questionnaires, overestimate "real" PA levels [4]. Nevertheless, the correlations were comparable to those that have been reported for much more complex community-based assessments [20], a satisfying result when taking into consideration the shortness of the assignment.

The scoring system of the PAIR has been confirmed by the current analysis with the exception of the score "six" ("undertaking little walks outside the hospital; yes, sometimes"). This score showed a lower mean cumulative PA than the two scores before ("undertaking little walks outside the ward"). Thus, sometimes leaving the hospital for a walk seems to add less minutes to total cumulative activity, especially when looking at total activity time. This adds to the overall discussion with regard to the accuracy of accelerometers predicting "total PA" [26] and might reflect specific aspects of the rehabilitation environment that have not been identified in previous analyses in another cohort of inpatients (data not shown). Therefore, we have decided not to change the scoring system of the instrument yet.

With regard to absolute validity, there is evidence of clinically significant differences of ±2 points across the measurement range. However, because of its simple ordinal scale as compared to the continuous scale of the sensors it was not fully appropriate using Bland-Altman plots which require that the two methods for measuring the same characteristic use the same scale of measurement [5]. Still, it has to be acknowledged that further research is necessary to clarify the quality of the PAIR with regard to absolute validity across different inpatient populations.

Since its popularity increased, the validity of body-fixed sensors has been a matter of great debate. Still, recent validation studies often used sensor-based technology as objective standard activity measurements [7, 20]. This might not always be appropriate, because PA can of course be more than just moving the hands (actigraph-sensors) or ambulation (accelerometers, step-counts). Triaxial sensors, mounted to the waist or trunk or armbands that include additional sensors measuring skin temperature, galvanic skin response and heat flux could increase accuracy with regard to energy expenditure but might not fill in the gap of an exact classification of types of activities [26]. However, validity of back- or hip-mounted triaxial accelerometers was very comparable to the mentioned armband in a recent study in patients with chronic obstructive pulmonary disease [39]. In addition, when thinking of geriatric rehabilitation, ambulation is still the most important component of PA and also the primary treatment goal of patients, caregivers and the therapeutic team alike [8, 9]. Therefore, when developing the PAIR the focus was set on walking tasks.

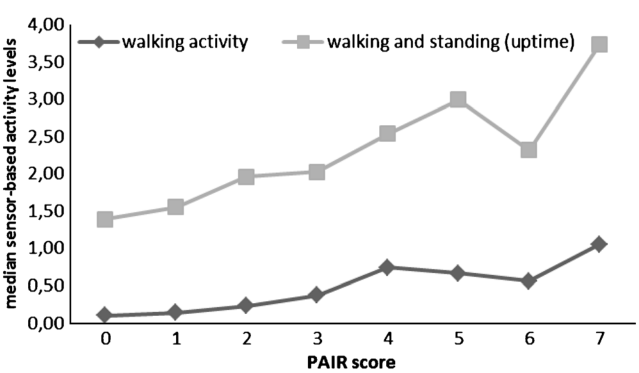

Fig. 1 Scoring system of the PAIR—median cumulative sensor-based activity scores are plotted against the PAIR score. The median cumulative walking and uptime activity (activity in minutes divided by the number of patients in each category) is plotted against the PAIR score for both results at admission and discharge (n=140). The continuous increase in uptime activity and overall activity does not account for the PAIR score "6"

Earlier analyses of the PAIR have demonstrated weak to moderate correlations with physical function assessments, especially if cognition was rated as intact or only slightly impaired [12]: Spearman correlations with gait speed or the Late Life Function and Disability Index ranked r=0.43–0.53. Together with these earlier results in a different population [12], the PAIR is the most thoroughly validated PA assessments for inpatients. With regard to the framework by Ainsworth and colleagues the development process of the PAIR can be considered at step six [1]. According to the two main questions in this step, it has to be stressed that the PAIR has been developed to provide a short and valuable PA assessment with the focus on mobility as the most important activity in geriatric rehabilitation rather than to provide a thorough assessment of metabolic equivalents (METs).

When validity results are compared to other new PA assessments in community-dwelling older adults, the PAIR seems to perform slightly better. This could be because of the less complex environment with an increased reminiscence of everyday tasks despite the higher overall cognitive deficit as compared to most other populations used [17]. Conversely, the less favourable outcomes of old and new community PA assessments have been attributed to the highly variable behaviour such as free-living physical activity by self-report [17].

There are more limitations to consider. Weak to at best moderate correlations pose problems during everyday use, especially when utilized as a screening tool. Significant misclassifications might preclude detailed analyses in especially smaller studies with low effect sizes [17]. Still, as mentioned by Helmerhorst and colleagues [17] the instruments are always useful on an individual basis and when analyzing PA trajectories in longitudinal projects. For that purpose, the good sensitivity to change of the PAIR, as demonstrated in previous analyses [12] is of importance. Because of its simplicity, repetitive assessments should not pose an additional problem in clinical practice. Another important limitation of the PAIR is that it has only been validated in patients able to walk at admission. There is no data so far on validity of this instrument in those that are bound to wheelchairs. This problem has been discussed in detail before [12] and warrants further studies. As demonstrated before, the PAIR also exhibited significant floor and (less) ceiling effects, naturally depending on levels of mobility of the participants studied. Yet, with the focus on inpatients, meaningful activities have been captured and application time, which we consider a very important aspect in a busy clinical practice, has been reduced to a minimum. Still, studies in populations with clearly better or clearly worse functional status (i.e. nursing homes or acute geriatric hospitals respectively) and additional "gold standard" validation techniques (doubly labelled water, diaries, or different sensors) would be helpful to improve relative validity of the PAIR.

To conclude, the PAIR is the currently best validated assessment of PA for (older) inpatients. It is concise and easy to administer. Although its validity is comparable to existing self-rated PA assessments for community-dwelling older adults, relative validity was only weak to moderate and doubts remain with regard to its absolute validity. More studies are warranted to confirm the scoring system and performance of the assessment in different inpatient populations.

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Conflict of interest All authors declare that they have no conflicts of interest.

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Ethical considerations All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained from all patients for being included in the study

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Individual contribution

Designed research: Becker, Denkinger, Flick, Lindemann, Nikolaus, Aminian. *Performed research*: Flick, Lindemann. *Analysed data*: Denkinger, Flick, Lindemann. *Wrote the paper*: Denkinger, Flick, Lindemann. *Critical revision*: Becker, Aminian, Nikolaus.